

EXTRATERRESTRIAL MÖSSBAUER SPECTROSCOPY: MORE THAN THREE YEARS OF MARS EXPLORATION AND DEVELOPMENTS FOR FUTURE MISSIONS

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The NASA Mars Exploration Rovers (MER), Spirit and Opportunity, landed on the Red Planet in January 2004. Both rovers are equipped with a miniaturized Mössbauer spectrometer MIMOS II [1]. Designed for a three months mission, both rovers and both Mössbauer instruments are still working after more than three years of exploring the Martian surface [2]. At the beginning of the mission, with a landed intensity of the Mössbauer source of 150 mCi, a 30 minute ‘touch and go’ measurement produced scientifically valuable data while a good quality Mössbauer spectrum was obtained after approximately eight hours. Now, after about five half-lives of the sources have passed, Mössbauer integrations are routinely planned to last ~48 hours. Because of this and other age-related hardware degradations of the two rover systems, measurements now occur less frequently, but are still of outstanding quality and scientific importance.

Summarizing important Mössbauer results, Spirit has traversed the plains from her landing site in Gusev crater and is now, for the greater part of the mission, investigating the stratigraphically older Columbia Hills. Olivine in rocks and soils in the plains suggests that physical rather than chemical processes are currently active [3]. Nevertheless, evidence for limited water interaction includes sulphur, chlorine and ferric iron enrichments in coatings of the rock Mazatzal [4]. Comparison of simultaneously acquired 14.4 keV γ -ray and 6.4 keV X-ray spectra provides depth sensitivity, and the average thickness of the coatings was estimated to approximately 10 μm [4]. Hematite and Goethite identified in rocks at the West Spur of the Columbia Hills show that water played a major role in the formation and alteration of rocks and soils in the Columbia Hills [6-8]. Home Plate is a layered plateau of probably explosive volcanic origin in the Inner Basin of the Columbia Hills [9]. Home Plate rocks are among the most magnetite-rich in Gusev crater.

Opportunity at Meridiani Planum journeyed across sulfate-rich outcrop, basaltic sand and dust, and hematite lag deposits [10]. The ferric sulfate hydroxide mineral jarosite was identified in sulfate-rich outcrop rocks. Millimeter-sized spherules were identified as the source of hematite detected from orbit [11]. This hematite signature was the reason to choose Meridiani Planum as a landing site. Crater hopping from her landing site in ~20 m Eagle crater via ~160 m Endurance crater, 300 m Erebus crater to ~800 m Victoria, Opportunity is currently searching for a safe ingress route to Victoria. Float rocks and

cobbles investigated along the way are of diverse origin. Mössbauer data were crucial to identify in Bounce Rock the first rock on Mars itself similar in composition to basaltic shergottites, a group of meteorites whose origin is believed to be Mars [12]. The identification of the iron nickel alloy kamacite in Heat Shield Rock and Barberton revealed an iron meteorite and a stony meteorite, respectively, the first to be discovered on Mars [13,14].

The primary MER objective was to explore two sites on the Martian surface where water may once have been present, and to assess past environmental conditions at those sites and their suitability for life. The MER Mössbauer spectrometers identified aqueous minerals such as goethite in Gusev crater and jarosite at Meridiani Planum. Jarosite forms under acidic conditions which would have challenged prebiotic chemical reactions, but microbial populations on Earth have adapted to low pH levels. Mössbauer spectroscopy thus proved to be a valuable tool for the field of Exo/Astrobiology [15].

With the Russian Phobos Grunt mission scheduled to launch in 2009, MIMOS II will be a contact instrument for sample return from the Martian moon Phobos. MIMOS II is also part of the Pasteur payload for the ESA ExoMars rover designed to search for traces of past and present life and scheduled to launch in 2013. For that, the instrument will be further reduced in size and weight, and improved significantly in sensitivity [16].

References: [1] Klingelhöfer et al., J. Geophys. Res. 108(E12) (2003) doi:10.1029/2003JE002138. [2] Klingelhöfer et al., Hyp. Int. 170 (2006) 169-177. [3] Morris et al., Science 305 (2004) 833-836. [4] Haskin et al., Nature 436 (2005) 66-69. [5] Fleischer et al., Lunar Planet. Sci. 38 (2007) Abstract # 1701. [6] Klingelhöfer et al., Hyp. Int. 166 (2005) 549-554. [7] Morris et al., J. Geophys. Res. 111 (2006) doi:10.1029/2005JE002584. [8] Ming et al., J. Geophys. Res. 111 (2006) doi:10.1029/2005JE002560. [9] Squyres et al., Science (2007) accepted. [10] Morris et al., J. Geophys. Res. 111 (2006) doi:10.1029/2006JE002791. [11] Klingelhöfer et al., Science 306 (2004) 1740-1745. [12] Rodionov et al., Meteoritics & Planet. Sci. 39, Supplement (2006) Abstract # 5219. [13] Rodionov et al., Geophys. Res. Abstracts 7 (2005) EGU05-A-10242. [14] Schröder et al., Meteoritics & Planet. Sci. 41, Supplement (2006) Abstract # 5285. [15] Schröder et al., Planet. Space Sci. 54 (2006) 1622-1634. [16] Klingelhöfer et al., this conference.